

TECHNO-ECONOMIC EVALUATION OF WASTE LUBE OIL RE-REFINING IN SAUDI ARABIA

Mohammad Farhat Ali, Abdullah J. Hamdan and Faizur Rahman

DEPARTMENT OF CHEMISTRY

King Fahd University of Petroleum & Minerals

Dhahran, Saudi Arabia

Keywords: Waste Lube Oil, Re-refining, Economics

INTRODUCTION

About 80 million gallons of automotive lubricating oils are sold in Saudi Arabia. Much of this oil, after use, is actually contributing to the increased pollution of land because of indiscriminate dumping. Any scheme of secondary use of the waste lube oils would be of interest both for conservation of energy resources and for protection of environment. This paper discusses the secondary use for the used automotive lubricating oils. Process technology of Meinken, Mohawk and KTI were selected for the techno-economic feasibility study for re-refining used oil. Profitability analysis of each process is worked out and the results are compared.

In many countries the re-refining of the used oils has become an important industry. The objective of recovering high quality raffinates is attained through the use of widely differing techniques.

The processes concerned can be classified according to the chemical or physical method of used-oil pretreatment selected. Meinken process is based on chemical pretreatment whereas, both Mohawk and KTI processes employ physical methods involving distillation and eliminates the use of sulfuric acid thus providing a facility for safer operation than Meinken.

The plant capacity of two existing units in Jeddah are 10,000 TPA and 80,000 TPA re-refining of waste oil. We selected a plant of 50,000 TPA waste oil re-refining for economic study of these three processes.

Both Mohawk and KTI have been running full range plants in different parts of the world and appear to be efficient and viable. Meinken have successfully implemented more than 60 used oil re-refining plants world wide including Kuwait Lube Oil Company, Iran Motor Oil Company, Saudi Lube Oil Company Limited, Jeddah, and Lube Oil Co. Ltd., Jeddah.

PROCESS TECHNOLOGIES

Meinken Process

The used oil is supplied to the re-refinery by railway tankers, road tankers or in barrels. Before the used oil flows into the waste oil storage tanks, it passes through the filters to remove solid impurities. A block flow diagram of re-refining process is shown in Figure 1.

Meinken process is based on chemical pretreatment [1]. The dewatered oil is treated with sulfuric acid (96 %) and the acid refined oil is vacuum distilled to separate lube base oil from the low boiling spindle oil and gas oil. With sulfuric acid treatment it is necessary to dehydrate the feedstock completely before subjecting it to acid treatment to prevent dilution of the concentrated sulfuric acid. On the other hand, there is no need to remove crankcase "dilution" or fuel components ahead of the acid-treating step, since these could be conveniently stripped from the hot oil in the subsequent clay contacting step. Their presence during acid treatment reduces the viscosity of the oil and thereby increase the ease of separating the acid sludge. However, the sulfuric acid - treatment and clay addition produce waste streams like acid tar and spent clay resulting in a problem of waste disposal. In spite of the disposal problem associated with Meinken process, the Meinken technology appears to be very popular. At present, there are about 60 such refineries around the world using the same system. New refineries of this type are in various stages of construction and planning in Kuwait, Saudi Arabia, UAE, Oman and India manifesting the technology to be well proven and widely accepted.

Mohawk Process

A simplified block flow diagram of the Mohawk-CEP process is shown in Figure 2. This is claimed by the licensors to be the newest and yet proven high-efficiency re-refining technology. Mohawk technology has been licensed to Chemical Engineering Partners, a private chemical engineering design company based in California, U.S.A.

The first stage of the process removes water from the feedstock [5,6]. The second stage of the process is distillation, at this step light hydrocarbons are removed resulting in a marketable

fuel by-product. The third stage, evaporation, vaporizes the base oil, separating it from the additives, leaving behind a by-product called residue. This residue is used in asphalt industry. The final processing stage is hydrotreatment which results in a high quality base oil.

The Mohawk process features continuous operation, low maintenance, longer catalyst life span, reduced corrosion, and proven technology.

KTI Process

Kinetic Technology International (KTI) of the Netherlands, in close cooperation with Gulf Science and Technology Co. (Pittsburgh, Pa.) has developed a new re-refining process for all types of waste lubricating oils [5,10].

The KTI waste lube oil re-refining process involves a series of proprietary engineering technologies that affords high economic returns without resulting in environmental loads. The main features of the KTI process include : (a) high recovery yield up to 95 % of the contained lube oil; (b) excellent product quality; (c) flexible operation with wide turndown capability; (d) no requirement for discharging chemicals or treating agents; (e) absence of non commercial by-products; and (f) reliable, inexpensive treatment of waste water contained in the wasted lube oil.

The important steps of this process are as follows. Atmospheric distillation, which removes water and gasoline. Vacuum distillation using special wiped film evaporators separates lube oil from heavy residue containing metals and asphaltenes. The next step is hydrofinishing of lube oil. Hydrogen rich gas is mixed with the oil and heated before passing through the reactor. The treated oil is then steam stripped or fractionated into cuts using a vacuum in order to obtain the right specification.

ECONOMIC EVALUATION

Capital Investment

The total fixed capital investment to process 50,000 TPA of waste oil was obtained from Meinken [1] and Mohawk [6] in 1991. Location factor of 1.25 was used to estimate the fixed capital costs for Saudi location [2]. Table 1 lists the total fixed capital investment estimated for both the technologies. Working capital for the re-refinery was estimated by itemizing the production costs components [12]. It varies with changes in raw material prices, product selling price and so on.

Economic evaluation of KTI process could not be carried out because of non-availability of complete cost data.

Production costs

Production costs consists of direct costs, indirect costs and general expenses.

Direct cost includes expenses incurred directly from the production operation. These expenses are : raw materials (including delivery), catalysts and solvents, utilities, operating labor, operating supervision, maintenance and repairs, operating supplies, royalties and patents.

Raw material prices were estimated from F.O.B. prices in Germany in September 1991 [1,3] and includes \$90.0 per ton for shipping. Local price was used for sulfuric acid. Collection cost of waste oil in Jeddah [1], Saudi Arabia was estimated as \$53.52 per ton. By-product(gas oil) price \$110 per ton was taken from Petroleum Economist[9], for Caltex, Bahrain location. By-product asphalt price \$130.0 per ton was taken from CMR [3], but reduced by 15% as it needs some more processing. If the asphalt residue can not be sold at international price due to low demand in this region, its price has to be further reduced. For economic analysis purposes, the price of asphalt residue was still lowered by 50 %. This is an approximation and the price used finally in the calculations is \$55.0 per ton of asphalt residue.

The raw materials, utilities, and manpower requirements are given in Table 2 which were obtained from Meinken [1] and Mohawk [8]. Table 3 lists raw materials, utilities and manpower costs estimated for Saudi Arabian location [2,11]. Natural gas price was taken as \$0.5 per million Btu [2] and the benefit of low price of natural gas is reflected in utilities costs such as electricity and steam. However, process water is expensive in Saudi Arabia because it is produced from desalination plants.

Operating costs which includes operating labor, supervision, maintenance and repairs and indirect costs which includes overheads, storage and insurance, and general expenses were estimated according to the standard procedures [7,13,14].

Summation of all direct costs, indirect costs and general expenses results in a production cost. Table 4 illustrates production cost of re-refining waste oil resulted from the two technologies. The estimated production cost for Meinken process was \$ 348.8 per ton and for Mohawk process it is \$ 198.4 per ton of re-refined oil.

For Meinken process the raw materials cost is about 54 % of the production cost. Utilities is 3.0 %, operating cost is 17.2 %, total indirect costs is 20.4 % and general expenses are 25.4 % of the total product cost. The share of raw materials cost in the total product cost is dominant.

In case of Mohawk process the raw materials cost is about 42.7 % of the total product cost. By-products are 12.4 %, utilities are 8.8 %, operating cost 23.0 %, total indirect costs are 25.4 % and general expenses are 12.5 % of the total product cost. So, the production cost will be sensitive to raw materials prices and sensitivity analysis was performed for different raw materials price.

Profitability Analysis

The profitability of an industrial opportunity is a function of major economic variables such as product selling price, raw materials prices, capital investment, energy prices and so on. Year-by-year cash flow analysis have been carried out using assumptions and financial arrangements described in Table 5.

From the analysis of production costs (Table 4) components, it is obvious that the raw materials cost is the dominant item. So, sensitivity analysis were performed for 15 % lower and 15 % higher raw materials prices than prevalent in September 1991.

Since the re-refined oil is not segregated into different neutral oils and bright stock, following typical composition was assumed: 10 % 300 SN, 80 % 500 SN and 10 % bright stock. Based on LUBREF, Jeddah [4] base oil prices of various grades an estimated selling price of \$415.60 per ton is used in the financial analysis.

The year-by-year cash flow analysis for international raw materials prices (base case) in September 1991 and for 15 % lower and 15 % higher raw materials prices have been carried out. The results of cash flow analysis are summarized in Table 6. Figure 3 shows the effect of raw materials prices on internal rate of return (IRR).

The total fixed capital investment is very high for Meinken process (28.750 million \$) as compared to Mohawk process (17.713 million \$). The working capital amounts to a high value of 4.998 million U.S. Dollars for Meinken as compared to relatively low value of 3.050 million Dollars for Mohawk.

The payback period(PBP) and break-even-point (BEP) for Meinken Process are high as expected compared to Mohawk process, which are 8.16 years and 53.8 % of the full production. The PBP for Mohawk is 1.40 years, and BEP is 28.65 %. The IRR for Meinken and Mohawk are estimated to be 11.24 % and 45.36 %. Thus, the total positive annual cash flow for Mohawk process appears to be more attractive than that for Meinken. The high profitabilities of Mohawk process are due to lower capital costs as a result of (i) excluding hydrogen plant and (ii) possibly due to relatively not well established technology as compared to Meinken process.

The main disadvantage of Mohawk process is that, the plant has to be located near a refinery or petrochemical plant (because of hydrogen supply) to be able to realize such high profitabilities. If the facilities are to be provided with an independent hydrogen plant, then the capital costs may go up significantly and subsequently profitabilities will be dropped.

ACKNOWLEDGEMENT

The investigators wish to acknowledge King Abdul Aziz City for Science and Technology (KACST) for funding this Research Project (AR-10-60). The facilities and support provided by the Department of Chemistry and the Research Institute of King Fahd University of Petroleum and Minerals (KFUPM) is also gratefully acknowledged.

REFERENCES

1. B. Meinken, Private Communication, B. Meinken Project and Construction Management Consultants, Haltern, Germany, 1991.
2. SRI, PEP Yearbook International, Volume 1, SRI International Menlo Park, California, U.S.A., 1989.

3. Chemical Marketing Reporter, Schnell Publishing Company, Inc., New York, U.S.A., September 1991.
4. LUBEREF, Private Communication, Petromin Lubricating Oil Refining Company, Jeddah, Saudi Arabia, 1991.
5. Ali, M. F. and Hamdan, A. J. Studies on Used Lubricating Oil Recovery and Re-refining, Third Progress Report, KACST AR-10-60, KFUPM, Dhahran, 1990.
6. Magnabosco, L.H., M. Falconer and K. Padmanbhan, The Mohawk-CEP Re-refining Process, The Proceedings of Sixth International Conference on used oil Recovery and Reuse, San Francisco, California, May 28-31, 1991.
7. Garrett, D.E., Chemical Engineering Economics, Van Nostrand Reinhold, New York, U.S.A., 1989.
8. Mohawk, Private Communication, Mohawk Lubricants, A Division of Mohawk Oil Co. Ltd., Burnaby, B.C., Canada V5G 4G2, 1991.
9. Petroleum Economist, p.31, June 1991.
10. KTI, Waste Lube Oil Re-refining for King Fahd University of Petroleum and Minerals, Dhahran, Document No. 10091, Kinetic Technology International Corp., California, U.S.A., 1989.
11. TECNON, List of Heavy Petrochemical Industries for Royal Commission for Jubail and Yanbu, Madinat Yanbu Al-Sanaiyah, K.S.A., TECNON (UK) LTD., Petrochemicals Marketing and Planning Consulting Services, London, U.K. 1988.
12. Bechtel, L.R., Estimate Working Capital Needs, Chemical Engineering, 67 (4): 127 1960.
13. Axtell, O., Economic Evaluation in the Chemical Process Industries, John Wiley and Sons, New York, U.S.A., 1986.
14. Ulrich, G.D., A Guide to Chemical Engineering Process Design and Economics, John Wiley and sons, New York, U.S.A., 1984.

Table 1. Capital investment of 50,000 TPA waste oil re-refining plant in Saudi Arabia.

Process Technology	Total Fixed Capital in 1991 (Million US \$)
Meinken, Germany	28.750
Mohawk, Canada	17.713

Table 2. Raw materials utilities and manpower requirements per ton of product.

	Meinken process	Mohawk process
Raw Materials:		
• Waste oil, ton	1.266	1.343
• Sulfuric Acid, ton	0.095	-
• Activated clay, ton	0.049	-
• Lime, ton	0.214	-
• Ammonia water(23%), ton	0.008	-
• Catalyst, kg	-	3.76
By Products:		
• Gas oil, ton	- 0.060	- 0.135
• Asphalt, ton	-	- 0.176
Utilities:		
• Fuel oil, ton	0.075	0.116
• Cooling water, ton	-	2.003
• Process water, ton	75.000	97.020
• Hydrogen, ton	-	0.003
• Steam, ton	-	0.667
Manpower:		
• Total men for 3 shifts	33	31

(-ve) Sign indicates by-product

Table 3. Raw materials, utilities and manpower costs in Saudi Arabia.

Item	Cost (\$/unit)
Raw Materials:	
• Waste oil, ton	53.52
• Sulfuric Acid, ton	160.00
• Activated sludge, ton	673.00
• Lime, ton	316.00
• Ammonia water (23%),ton	387.00
• Catalyst, kg	3.41
Utilities:	
• Fuel oil, ton	110.00
• Cooling water, ton	0.019
• Process water, ton	0.803
• Electricity, Kwh	0.015
• Hydrogen, ton	65.000
• Steam, ton	4.630
Manpower:	
• One man year (\$/year)	18,000

Source: [1, 2, 3, 11]

Table 4. Production cost data.

Parameter	Meinken Process	Mohawk Process
<u>Direct Costs:</u>		
• Raw materials	188.21	84.70
• By-products	-6.64	-24.52
• Operating Cost	70.63	63.08
Indirect Cost	71.03	50.34
General Expenses	25.56	24.82
Total production cost	348.79	198.41

Table 5. Basis of financial calculations.

Item	Calculated Basis
Project life	20 years
Construction period	3 years
Depreciation method	Straight line
Salvage value	Zero
Equity/SIDF loan	50% each
SIDF Loan fee	3%
Loan payment	7 equal installments starting 2 years after plant start-up
Tax rate	2.5 %
Inflation	0.0 %
Capital expenditure:	
• 1st year	20% of fixed capital
• 2nd year	45% of fixed capital
• 3rd year	35% of fixed capital plus working capital
Capacity utilization:	
• 1st year	60%
• 2nd and subsequent years	100%

Table 6. Profitability of re-refining 50,000 TPA waste oil in Saudi Arabia (1000 \$)

	Meinken Process	Mohawk Process
Total fixed capital	28,750	17,713
Working capital	4,999	3,111
SIDF loan	16,875	11,356
Annual variable expenses	7,587	2,873
Annual fixed expenses	4,746	3,852
Annual sales	16,410	15,377
Payback period (years)	8.2	1.4
Break-even-point (% capacity)	53.8	28.7
IRR (%/year)	11.2	45.4

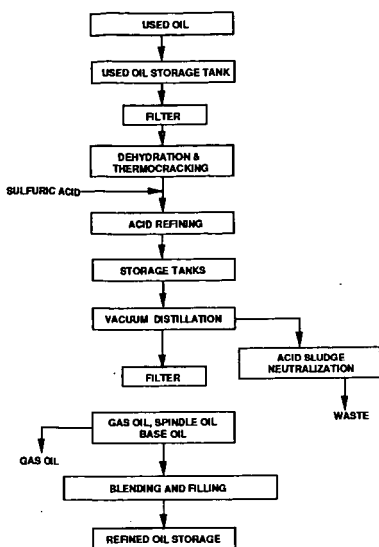


Figure 1. Block flow diagram of Re-refining of used oil by Meinken process

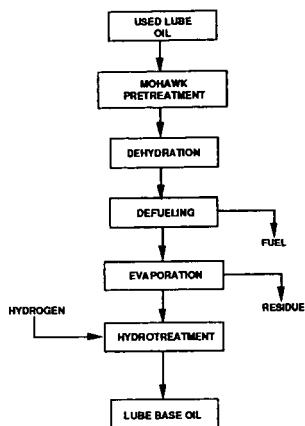


Figure 2. Block flow diagram of Re-refining of used oil by Mohawk-CEP process.

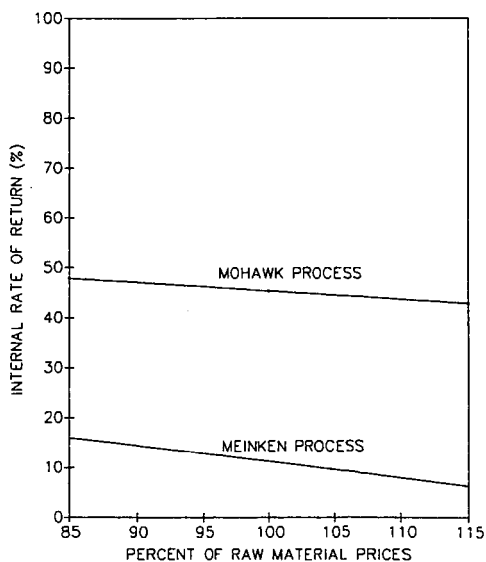


Figure 3. Effect of raw material prices on IRR.